M.O. 501 AIR MINISTRY

METEOROLOGICAL OFFICE

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METEOROLOGICAL RESEARCH FLIGHT

BY RONALD FRITH, M.A., Ph.D.

From the time, a century or two ago, of the earliest meteorological measurements in the free air, our knowledge of conditions in the troposphere and lower stratosphere has increased, at varying rates, through observations obtained from manned balloons, kites, sounding balloons, pilot balloons and, within about the last 30 years, aircraft and radio-sondes. Before 1939, the number of routine soundings enabled upper air pressure and temperature charts to be prepared regularly for certain areas. The years of war saw a greatly increased use of radio-sondes for determination of temperature and humidity to heights in excess of normal aircraft ceiling, and the introduction and extended use of radio and radar methods for wind measurements.

Nevertheless the information obtained, whether from aircraft or radio-sonde, was far from complete. For example, humidity measurements, except at comparatively high temperatures, were either lacking or inaccurate. The presence of cloud, and its type, could be reported from an aircraft, but no measurements could be made of its density (liquid or solid content) or the number and size of its particles.

It was believed that knowledge of these quantities would not only benefit the general science of meteorology, but would be of great value in connexion with two special problems thrown into prominence by the war—icing and condensation trails.

So, in 1942, it was arranged that the High Altitude Flight at Boscombe Down should give facilities for meteorological investigations to be carried out by meteorologists in aircraft. The initial objective was the improvement of existing aircraft meteorological instruments and the development of new ones. It was expected that in the course of this work the research unit would accumulate valuable meteorological data. This expectation has been justified.

Early work.—*Temperature measurements* made from aircraft require correction for the speed of the aircraft. With fast, high-flying aircraft this correction is very large (in excess of 20°F.). It had been realised for some time that existing determinations of the " speed correction coefficient " were not sufficiently accurate, so one of the first tasks imposed on this new unit was to

measure these coefficients and to assist the Instruments Division of the Meteorological Office in the design and development of new thermometers.

Many types of thermometer were tested and eventually a completely new, distant-reading, electrical instrument was developed. This, the flat-plate electrical thermometer, is rapid in response and very accurate. It is suitable for all types of aircraft, including single-seater single-engined types, and is now widely used.

Humidity measurements.—Rapid progress was also made by Dr. G. M. B. Dobson of Oxford University in association with Mr. A. W. Brewer, the Meteorological Officer of the flying research unit, in the development of an aircraft frost-point hygrometer.

At this time there were two standard ways of measuring the humidity in the upper air—(i) the wet- and dry-bulb psychrometer; (ii) hygrometers using some substance responsive to changes in humidity (hair, goldbeater's skin, etc.). Both of these, satisfactory enough at moderate or high absolute humidities, fail completely at low absolute humidities. It was hoped that a frost-point hygrometer would work down to the lowest humidities likely to be found within the range of present-day aircraft. This proved to be the case, and on December 22, 1943, the new instrument was used on an ascent which penetrated the stratosphere. Fig. 1 shows the results of this sounding. These are believed to be the first reliable measurements of humidity ever made in the stratosphere.

Since then some 50 similar ascents have been made.

At low levels too, the instrument gave information of great interest. Frost points as low as −50°F. and relative humidities of less than 1 per cent. were found to be not uncommon in subsided air.

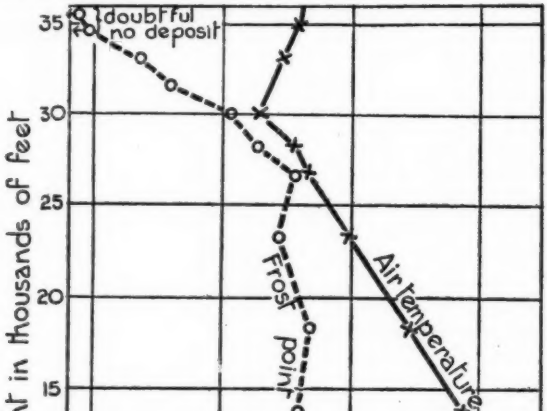


FIG. 1—THE FIRST ASCENT WHEN HUMIDITIES WERE MEASURED IN THE STRATOSPHERE
Boscombe Down, December 22, 1943

In 1946 the research unit was transferred to the Royal Aircraft Establishment at South Farnborough, re-equipped with two Halifax and two Mosquito aircraft, and renamed the Meteorological Research Flight.

Meteorological Research Flight.—Although the flight is still very much concerned with the development of aircraft meteorological instruments, a regular part of the work now consists in the use of instruments previously developed, either here or elsewhere, for the study of the atmosphere.

High-level and high-speed work.—About 10 ascents into the stratosphere, using Mosquito aircraft, are aimed at each month. The ascents generally reach 39,000 or 40,000 ft. and take about $1\frac{1}{4}$ hr.

Especially since the installation of remote-controlled frost-point hygrometers, in which the frost is " seen " photo-electrically, these trips (if nothing goes wrong) can be quite pleasant.

It is also planned to use these aircraft to assist in the development of totally different methods of measuring humidity at very high levels.

Apart from this humidity work, Mosquito aircraft are also used to check the air-temperature speed corrections at high speeds, and at high levels. This work is tiring. It entails flying, generally at 30,000 ft., to and fro, in the same air as near as can be determined, and at various speeds. A complete run consists of eight legs, on each of which the aircraft is flown steadily for a minute or two at each of the following speeds: 220, 240...360 m.p.h. Such a run takes about $2\frac{1}{2}$ hr. But so variable are the air temperatures that the means of the eight readings obtained at each speed still do not lie smoothly on a curve; and a great many similar runs are required before a firm value for the speed correction cofficient can be found.

Medium- and low-level work.—The Halifax aircraft are used for work up to 20,000 ft. This consists mainly of:—

(*a*) A study of the " fine " structure of the atmosphere. This work is of importance, for example, in connexion with turbulence and generally atmospheric stability.

(*b*) A study of the structure of clouds and of the development of rain.

For some time work under (*a*) consisted mainly of detailed readings of temperature and humidity during a slow ascent or descent. These readings appeared to show that " subsidence inversions " were very common, and very complex. However it has been lately realised that variations in the horizontal also are often quite large, and special attention is now being given to mapping temperature and humidity over horizontal areas, generally of about 30 mi. × 20 mi. Fig. 2 shows such a map.

It takes 2–$2\frac{1}{2}$ hr. to make a survey of this size and requires at least three observers—one to operate the frost-point hygrometer, one to operate the electrical thermometer and the third to take readings of airspeed, height, position, etc. If possible, a fourth observer makes independent temperature readings.

A number of these surveys have now been made under widely differing synoptic situations. Broadly speaking they show temperature and humidity patterns, generally closed, on a scale measured in tens of miles, with a temperature range of about 1°F. and a frost-point range of 10–20°F. or even more.

The frost-point and temperature isopleths are generally similar, dry air being warm, and moist air cold.

Item (*b*), the study of the structure of clouds and of the development of rain, is perhaps the most interesting of all our work. It is certainly the most difficult. It involves:—

(i) The measurement of the numbers and sizes of cloud particles and of rain drops.

(ii) The recognition of ice crystals as distinct from water droplets in a cloud.

(iii) The study of where and how rain develops.

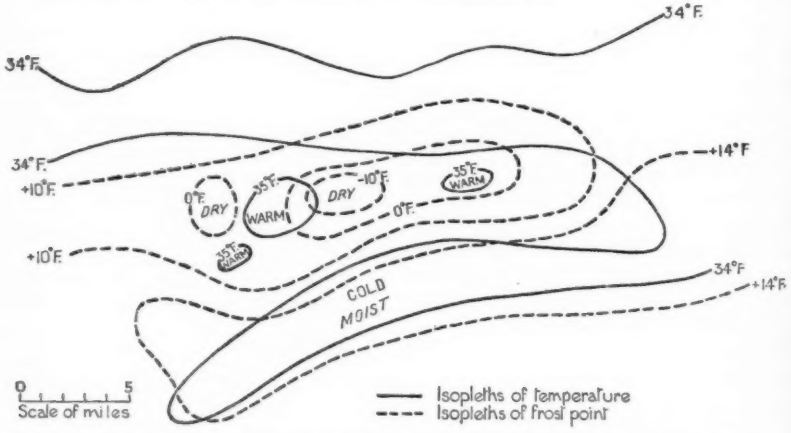


FIG. 2—ISOPLETHS OF FROST POINT AND TEMPERATURE AT 10,000 FT. OVER SOUTH MIDLANDS, APRIL 27, 1948

At present qualitative measurements are obtained of the sizes and the numbers of cloud particles by exposing in the cloud for a short period (1/100 sec.) a microscope slide in a suitably designed container. The slide is coated with soot, magnesium oxide or a green gelatine film. Using any of these coatings each cloud particle which strikes the slide leaves a pit or stain. By examining the slide under a microscope, counting and measuring the pits or stains, a qualitative picture of the size distribution is obtained and thus of the water content in the cloud. Figs. 3 and 4 (facing p. 252) show a typical slide magnified 100 times and work in progress in the aircraft.

Ice crystals leave an irregular pit on the soot- or magnesium-oxide-coated slides and can thus be recognised.

Other instruments are in course of development which will make similar measurements either photographically or, in supercooled clouds, by measuring the rate of ice formation on rods of different diameters.

Work is also progressing, in co-operation with the Instruments Division of the Meteorological Office, on apparatus, suitable for use in aircraft, for measuring the sizes of drizzle and rain drops.

The formation of rain is studied in two ways; first, by making ascents through warm-front cloud systems, and observing visually and instrumentally all that is to be observed, and secondly, by studying the development of cumulus clouds as they grow into shower clouds.

The study of the development of cumulus clouds has presented a quite unforeseen difficulty in the rapidity with which these clouds grow and decay, so that a promising-looking cloud, by the time one has reached it, is either a fully developed cumulonimbus, or else has practically disappeared. In this way one can fly about from cloud to cloud for hours without ever being present when a cumulus cloud begins to precipitate.

Ground work.—In the preceding sections stress has largely been laid on work in the air. On the ground there is, on the one hand, a good deal of work to be done in measuring and counting, in computing and tabulating; and, on the other, there are always past results to study, to write up and, if possible, to explain.

For the instrument-development work the flight has its own workshop, and employs an instrument maker.

So, whether it is a " flying day " or not, there is always plenty of interesting work to be done, and, perchance, new discoveries to be made.

CALCULATION OF THE RELATIVE HUMIDITY WHEN THE AIR TEMPERATURE IS BELOW 32°F.

BY R. H. COLLINGBOURNE, M.SC.

The relative humidity, U, is defined* by the relation $U = 100\ r/r_w$ where r is the mixing ratio of the air and r_w is the saturation mixing ratio at the same temperature and pressure. This is, however, for most practical purposes, equivalent to

$$U = 100\ e'/e'_w$$

where e' is the vapour pressure of the air and e'_w is the saturation vapour pressure at the temperature of the air T. When, however, the air temperature is below 32°F. the saturation vapour pressure has two possible values, the saturation vapour pressure over ice and the saturation vapour pressure over supercooled water. There are therefore two values of the relative humidity under these conditions and a convention has to be adopted as to which is used. The present Meteorological Office practice is to calculate the relative humidity with reference to saturation over ice, but it is proposed that, after January 1, 1949, in accordance with a resolution passed by the Conference of Directors in 1947, the relative humidity shall be calculated with reference to saturation over liquid water at all temperatures. The revised definition will give lower values of the relative humidity at temperatures below 32°F. It is the purpose of this note to show what changes will be necessary in the present method of using the Bilham humidity slide-rule to calculate the relative humidity.

The humidity slide-rule, designed by E. G. Bilham†, is used at most Meteorological Office stations. The instrument, at present in use, is designated the Mk. II and differs in a number of points from that originally described by Bilham, which is now called the Mk. I. In the Mk. II (illustrated facing p. 253), scale 4, on the upper edge of the slide, is a scale of temperature such that the distance of any graduation mark, T, from a certain fixed point is

*I.M.O. Conference of Directors, Washington, D.C., Resolution 166, 1947.

†BILHAM, E. G.; A slide-rule for hygrometric calculations. *Met. Mag., London,* **70**, 1935, p. 254.

equal to the value of $\log e'_w$ on the same scale as the logarithmic scale 5 on the top of the stock. The point marked with an arrow and the letters R.H. is the value of T for which e'_w is equal to 100 mb. The usual operation for calculating the relative humidity is thus equivalent to finding the value of $100\ e'/e'_w$ by normal slide-rule methods. At temperatures below 32°F. the values of e'_w used in graduating scale 4 correspond to saturation over ice and incorrect values of the relative humidity, on the new definition, will therefore be obtained in these conditions.

In these cases it is, however, possible to find an " adjusted " dry-bulb temperature such that the saturation vapour pressure over ice at this temperature is equal to the saturation vapour pressure over supercooled water at the true dry-bulb temperature. If this adjusted dry-bulb temperature is then used in the normal way in place of the true dry-bulb temperature the correct value of the relative humidity will be obtained. This adjusted temperature can be found by putting the cursor over the value of the true dry-bulb temperature on scale 1a and reading the adjusted dry-bulb temperature on scale 1 (the saturation vapour pressure over supercooled water at the true dry-bulb temperature is given by the reading of the cursor on scale 2 and this also equals the saturation vapour pressure over ice at the reading of the cursor on scale 1). The adjusted dry-bulb temperature is always greater than the true dry-bulb temperature.

The procedure can be summarised as follows:—

(*a*) Find the vapour pressure e' in the normal way (note that scale 3a should be used in place of scale 3, or scale 3c in place of scale 3b if an Assmann psychrometer is being used).

(*b*) Place the cursor over the value of the dry-bulb temperature on scale 1a and read off the adjusted dry-bulb temperature on scale 1.

(*c*) Use in the normal way the value of e' already found and the adjusted dry-bulb temperature to find the relative humidity.

The values of e'_w at temperatures below 32°F. which were used in graduating scale 4 on the original Mk. I instrument correspond to saturation over supercooled water (i.e. this instrument would give the correct values of the relative humidity at all temperatures without the necessity of computing an adjusted temperature). A new model of the humidity slide-rule will be produced in the near future which will have scale 4 altered to correspond with that on the original Mk. I.

PHENOMENAL RAINFALL AT SEMMERING, AUSTRIA

BY A. H. GORDON, M.S. (Pasadena)

On June 5, 1947, between 1340 and 2045 local summer time the phenomenal precipitation of over 12 in. was recorded by the official Austrian meteorological reporting station at Semmering, near the existing boundary between the British and Soviet zones of occupation. The accuracy of this figure as an exact measure of the precipitation fallen is perhaps open to some doubt, because of the extraordinary circumstances prevailing. However, in view of the observations made during the storm and the damage which occurred there is little question but that a fall of excessive and " cloud-burst " proportions did occur.

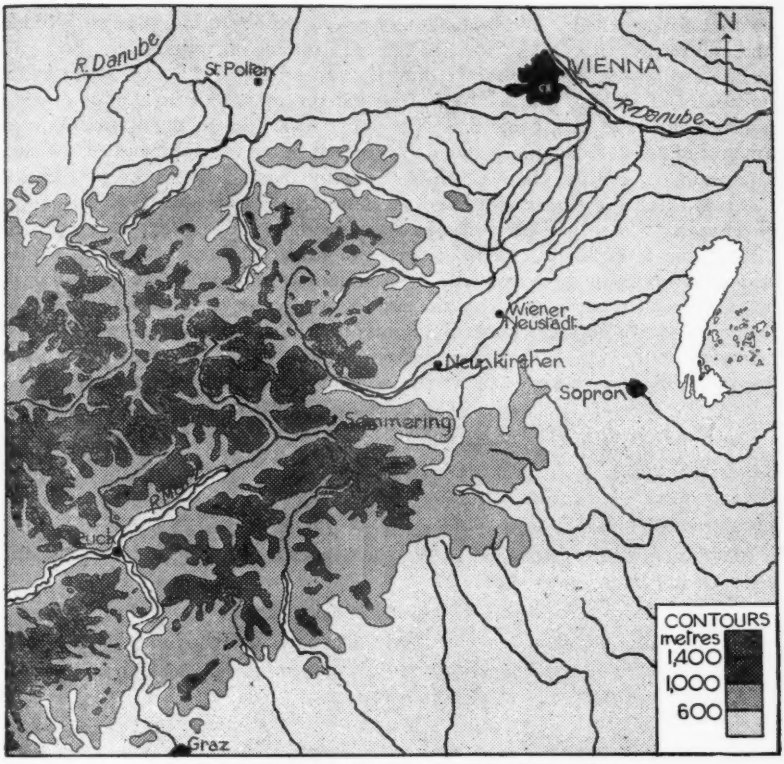


FIG. I—MAP OF THE AREA ROUND SEMMERING

The actual descriptive report from the observer at the Semmering station, as translated from the German and condensed, is as follows:—

On June 5, 1947, a violent thunderstorm, accompanied by a " cloud-burst " hailstorm began at 1340 and lasted until 1545. The hailstones were on the average the size of small cherries. At 1430 the funnel of the rain-gauge was already filled with hailstones to within a hand's width of its edge, congesting the outlet; so we took off the funnel, removed the can and put the hailstones into the gauge. From 1545 until 1600 there was a slight pause during which there was only heavy rain. The thunder and hail recommenced at 1600 and lasted until 1645. This time the hailstones reached the size of large cherries, weighing 4·3 gm. From 1750 to 1830 there was more thunder and hail, the hailstones reaching the size of cherry stones. The hailstorm was unusually heavy. It rained uninterruptedly from 1340 to 2045. From 1845 to 2030 and from 2105 to 2145 thunder was heard and lightning seen. The ground was partially covered with hail 20 cm. deep. The district gave one the impression of a winter landscape.

To measure this extraordinary amount of rain, at 1915 we emptied the gauge* into two large receptacles and carried the water indoors. The hailstones had

*See p. 250 for description of rain-gauge.

by that time melted. We immediately re-erected the rain-gauge with funnel and collecting can. There was another 0·12 in. of rain until 2100. So as not to lose any water, we syphoned it into the official measure; and, to lessen the possibility of making a false count, emptied the measure into a glass cylinder which could hold about one litre of water. At the level corresponding to an amount of 20 mm. (0·79 in.), twice the content of the official measure, we fixed a paper mark and put the water into the cylinder which had been prepared in this way. The cylinder was filled 16 times which corresponds to a quantity of 320 mm. (12·6 in.). This work was done together by the observers, Frl. Emma Bittner and Herr Magister Krakowka; Frl. Lina Taschner was also a witness and took part in the measurement. As the quantity of rain was so extraordinarily large, we also made a notch in the side of the gauge at the level reached by the water so as to be able to check the quantity of water on a future occasion of heavy rainfall. On June 6 we again filled the gauge 32 times with water from the official measure to prove the accuracy of our measurements.

Readings (station level) at the time of the catastrophe

	1200	1400	1500	1600	1800	2000
Barograph (mb.) ..	894·6	895·2	..	897·2	897·4	897·2
Hygrograph (%) ..	56	99	..	97	96	96
Thermograph (°F.) ..	70	67	48	57	52	51

At Semmering on June 6 at 0700 at a temperature of 49°F. hail could still be found in places.

For the accuracy of this report:

EMMA BITTNER M.R. KRAKOWKA, Schoolmaster
Meteorological Observers

LINA TASCHNER
Witness

Summary of the damage caused.—The damage caused by the swollen rivers and by water rushing down the mountain sides into the narrow valleys was very extensive.

Bridges with iron girders were swept away. A railway embankment was destroyed at Semmering station leaving 30 ft. of track hanging in the air. Many roads had their surfaces destroyed for long distances and were left piled with rocks in places to a height of 6 ft. At one point a river changed its course and now flows along a former road. A rock wall, 26 ft. long and nearly a yard thick, was moved 3 yd. by water pressure and broken up against the rocks. The crops were totally destroyed in many fields. One death was reported.

The synoptic chart (Fig. 2) at 1200 G.M.T. on June 5, 1947, shows the general weather conditions just about the time of the commencement of the storm. The pressure distribution before the 5th had been very flat for about four days resulting in extreme heat over the whole of western Europe including the British Isles. Temperatures up to 92°F. had been recorded in Vienna and in the valleys of Austria during the period. The very hot weather was ended by the cold front shown in Fig. 2. The intensity of the storm at Semmering was of very local character. Elsewhere the passage of the front was accompanied by only light showers.

In Fig. 3, which gives the 700-mb. contours for 0600 G.M.T., the cold front is seen to be quite well marked at that level. The temperature at Sonnblick,

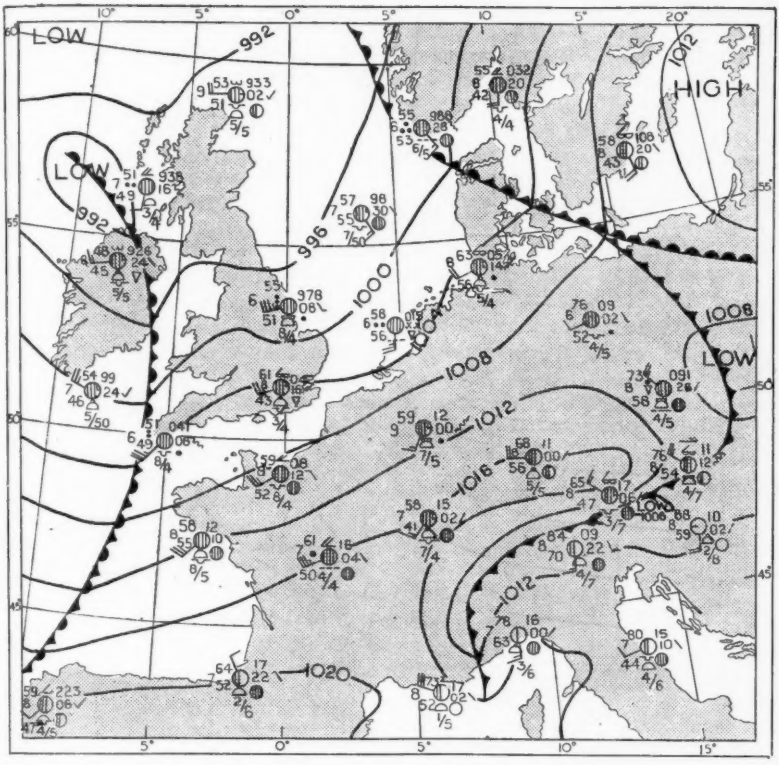


FIG. 2—SYNOPTIC CHART AT 1200 G.M.T., JUNE 5, 1947

approximately 10,000 ft. above sea level, is seen to be 45°F. At 1200 G.M.T it had dropped to 34°F. after the passage of the front.

The exact conditions responsible for the formation of a very moist and unstable pocket of air such as could produce such excessive precipitation are difficult to isolate and account for. Possibly such a pocket may have remained stagnant in a valley such as the Murztal for some days during the previous heat wave, continually drawing moisture from the numerous rivers and streams in the locality and from the rich verdant vegetation which prevails there. Such a pocket may have attained a high lapse rate, probably over 5°F./1000 ft. This, in itself, would not account for the unusual precipitation since such a lapse rate must have existed all along the cold front without causing anything exceptional. However, if the pocket had at the same time become very much moister than the surrounding air, it would have been capable of possessing the potential energy subsequently released. The arrival of the cold front, which may have driven the moist pocket north-eastwards up the Murz valley and over the high mountain slopes which surround the head of this valley, provided an external orographic effect sufficient to set this vast store of potential energy into violent action. The results have been ably shown already.

The formation of stagnant pockets of air in mountainous regions would

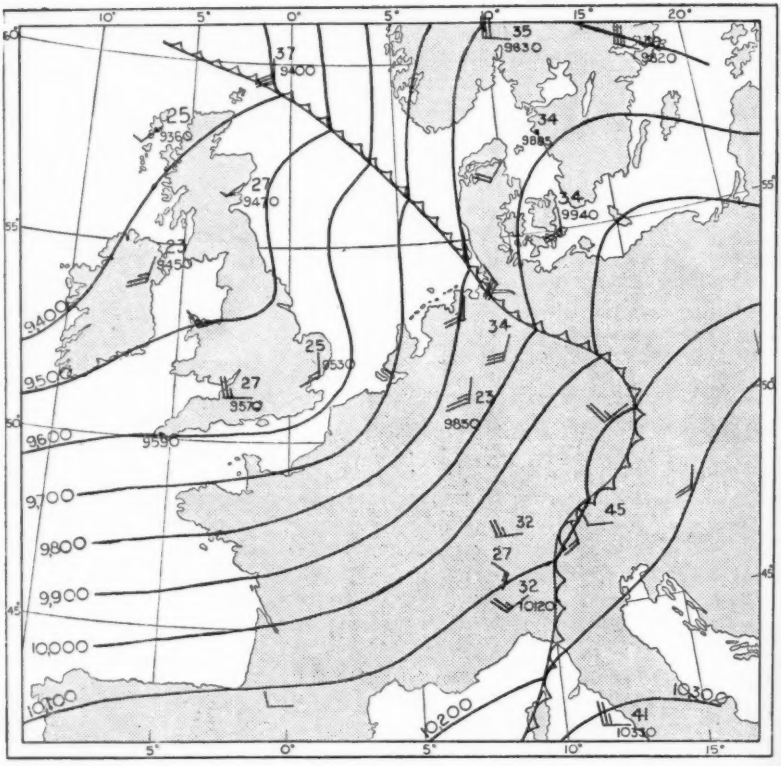
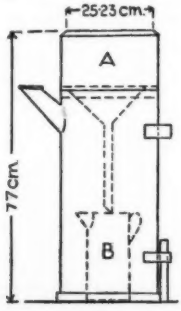


FIG. 3—CONTOURS OF 700-MB. SURFACE AT 0600 G.M.T., JUNE 5, 1947
The contours are drawn at 100-ft. intervals; the arrows fly with the wind, each feather being equivalent to 10 kt.

appear to dominate the local meteorology of these regions to a great extent and considerable investigation into this subject would appear to be needed.

[The type of rain-gauge used in Austria differs considerably from the British pattern. The Austrian one, 77 cm. high and 25·23 cm. in diameter, rests with its base on the ground and is held rigid by a wooden support. The diagram, copied from Kleinschmidt Fig. 1d, "Handbuch der meteorologischen Instrumente", p. 276, shows the construction.



The heaviest rainfall in a thunderstorm recorded in the British Isles was 9·56 in. at Bruton, Somerset, on June 28, 1917. At Cannington, Somerset, on August 18, 1924, 8 in. fell in 5 hr. The heaviest fall in one day on the continent of Europe appears to have been 18·3 in. at Riposto, Sicily, on November 17, 1910.*

This fall of 12·6 in. at Semmering in 7 hr. is certainly among the heaviest ever recorded in Europe.—Ed. *M.M.*]

METEOROLOGICAL RESEARCH COMMITTEE

The third meeting of the Instruments Sub-Committee was held on September 9.

The Sub-Committee discussed alternative proposals for producing some form of radio equipment capable of measuring upper winds at a lower cost (both in terms of initial financial outlay and of financial and manpower maintenance costs) than that of the equipment in current use in this country. It was decided that radar equipment in some form is the most probable answer but a decision between two alternative ways of using radar principles was deferred until certain trials have been carried out.

An interim report on progress being made in the production of a high-powered searchlight for the exploration of the atmosphere at heights above the limit of radio-sondes was received. The progress made is very promising.

Discussion also took place on the accuracy of radio-sonde observations.

LETTERS TO THE EDITOR

Climatic change

At the end of his interesting article " Changes in the climate of London " in May 1948 issue of *Weather*, Mr. E. L. Hawke invites a possible explanation of the several changes which are revealed by his investigation.

May not the answer be that the mean position of the polar front in the northern hemisphere has gradually moved northwards? This might also explain apparent climatic changes during recent times in other parts of the northern hemisphere.

The effect of a general northward movement of the polar front and therefore of the mean track of depressions associated therewith would, I think, account for the conclusions reached by Mr. Hawke if one bears in mind that, in the northern hemisphere, the polar front has an annual movement southwards (in the winter) and northwards (in the summer) of its mean position throughout the year as a whole.

If in the seventeenth century polar air penetrated much farther southward than it does today, then one would expect generally colder weather and more summer frosts then than now. Moreover, in view of the well known instability of maritime polar air, especially when heated from below as happens durings its passage over warm land surfaces in summer, there could have been maximum rainfall in spring-summer and a greater frequency of hail in the seventeenth century. Nowadays, in summer, London would be more often under the influence of the relatively stable air which originates from the subtropical high, with the result that precipitation frequency would tend to reach a maximum in autumn-winter when the polar-front depressions are most active

*BROOKS, C. E. P.; Abnormal rainfalls. *Met. Mag., London*, **62**, 1927, p. 1.

and effective. The more southerly track of depressions in the seventeenth century, causing unsettled weather and gales almost as often in the summer as in the winter, would also account for the greater movement of air and therefore fewer fogs which Mr. Hawke mentions as a feature of the period in question, 1669–89.

The reason for the northward drift of the frontogenetic zone of the polar front would, presumably, be some change in solar radiation resulting in a decrease of ice cover at the poles and a less extensive polar air mass—hence a diminishing and less vigorous southward movement of cold polar air?

R. G. VERYARD

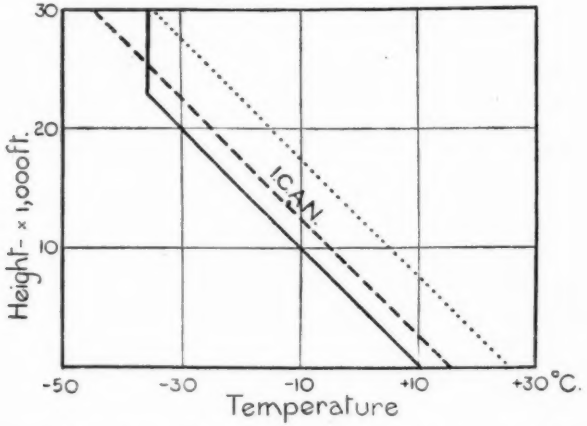
H.Q., R.A.F., Med./M.E., Ismalia, June 14, 1948

Notes on the I.C.A.N. altimeter and height and airspeed computor

In connexion with Mr. Bull's article "Notes on the I.C.A.N. altimeter and height and airspeed computor" in the issue of last February, it may be of interest to remark that use of the height and airspeed computor may sometimes appreciably *increase* the error of the altimeter.

This will occur, for example, when the aircraft is flying in the stratosphere, and the air temperature is higher than the standard I.C.A.N. temperature for that level. Tropopauses lower than 30,000 ft. are not infrequent, even in this country.

The figure makes this clear. The full line shows the actual air temperature, the pecked line shows the first approximation (I.C.A.N. atmosphere) and the dotted line shows the second approximation using the computor.



An example has been chosen almost at random. At Liverpool the 0000 G.M.T. ascent on October 24, 1944, showed a tropopause at 20,300 ft. The temperature at 30,000 ft. was −39°C. On an aircraft flying at a true height of 30,000 ft. the altimeter would indicate 30,660 ft. If the reading were "corrected" by means of a computor the result would be 31,500 ft., thus increasing the error from 660 ft. to 1,500 ft.

RONALD FRITH

Farnborough, Hampshire, May 24, 1948

[To face page 252

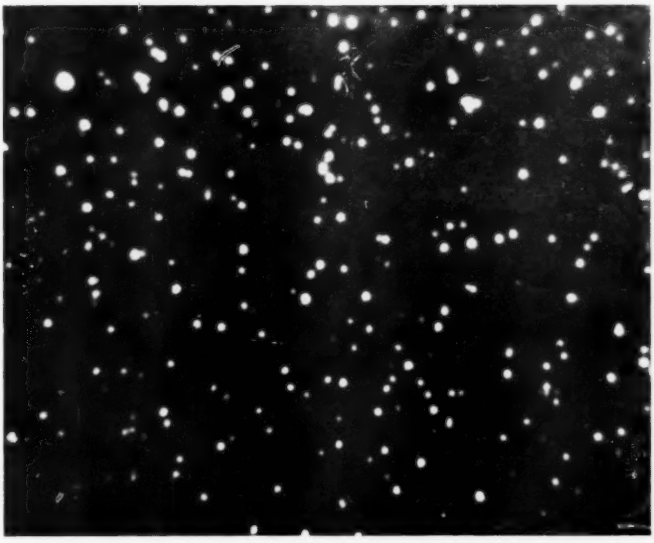
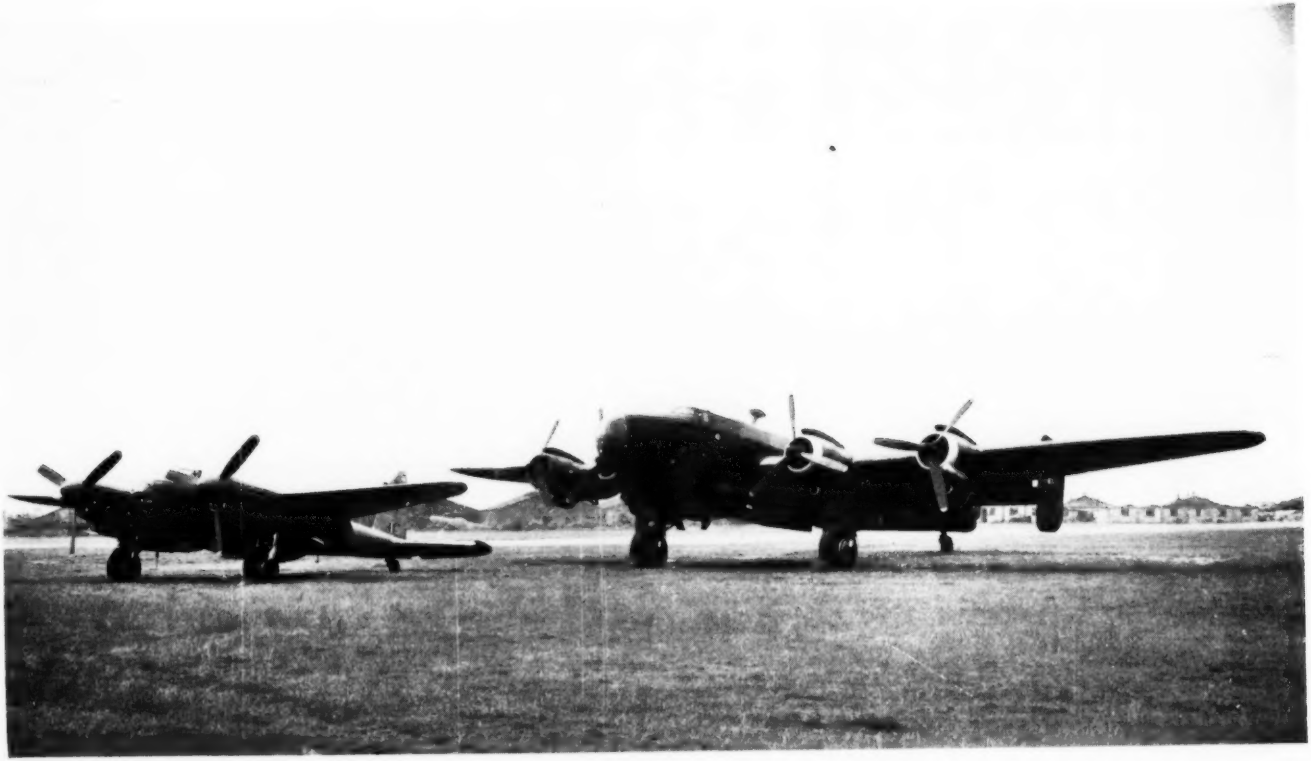


FIG. 3—CLOUD-PARTICLE PITS ON A MAGNESIUM-OXIDE SLIDE
(Magnification × 100)
Sample taken in stratocumulus at 2,000 ft., May 13, 1948

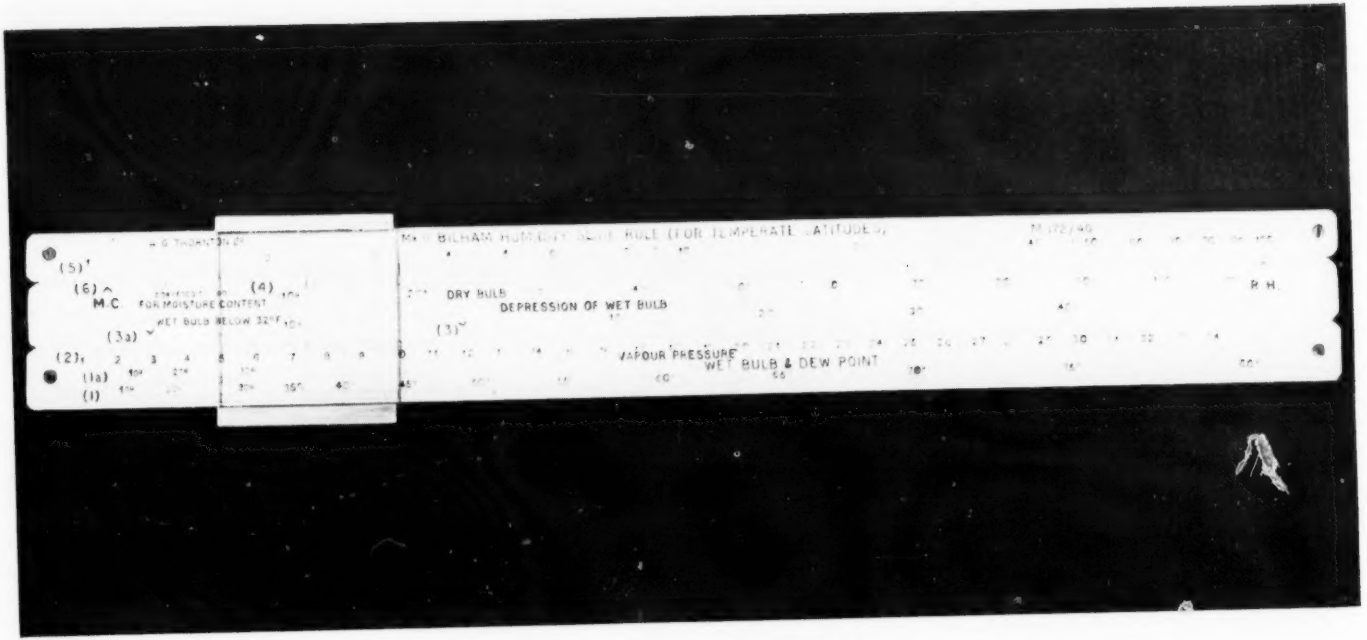
FIG. 4—MEASURING THE SIZE OF CLOUD PARTICLES FROM A HALIFAX
(see p. 244)



TWO AIRCRAFT OF THE METEOROLOGICAL RESEARCH FLIGHT

O.W.S. *Weather Observer* UNDERGOING MINOR REPAIRS AT STATION JIG, APRIL 1948
The two black shapes at the foreyard indicate that the ship is unable to manoeuvre.

[To face page 253]



BILHAM HUMIDITY SLIDE-RULE MK. II

(see p. 245)

Waterspouts and their danger to aircraft

During some work that I have recently been doing on the characteristics of waterspouts at sea, it occurred to me that these phenomena, which sometimes may be quite violent, might possibly account for the occasional inexplicable disappearance of aircraft at sea, particularly when that disappearance occurs at night in tropical and subtropical regions.

When an aircraft disappears without any form of earlier warning message or information being received that all is not well aboard, it would appear quite probable that the machine had come to a sudden, and in all probability a violent end. Such an end could quite reasonably be expected from collision in the dark with a waterspout column owing to its high rotational velocities.

The linear rotational velocities in a spout of only moderate intensity in temperate latitudes may reach the order of 100–200 kt., while those in the more violent tornado spouts, such as occur off the eastern seaboard of the United States, are believed to reach considerably higher. It is clear that the force behind such velocities would be capable of completely breaking up the strongest aircraft in a matter of a few seconds as a result of the huge strains inflicted on the component parts of the aircraft.

It is realised that a similar sort of occurrence could conceivably occur if an aircraft flies into the middle of a particularly violent cumulonimbus cloud in the dark. However, damage done to an aircraft by violent turbulence in a cumulonimbus cloud might not be as instantaneous as that done by an intense spout. It is possible that in the former case some warning of the danger that had been encountered might be sent out first. The height at which the aircraft is flying is an important factor since a damaging waterspout would normally be met below the cloud base. The captain of an aircraft might therefore consider that no bad weather danger existed if he was flying well below cumulonimbus cloud level. Neither need the waterspout column necessarily be met directly beneath the cumulonimbus cloud since the column frequently bends to a considerable distance away from the cloud from which it emerges. In daylight hours, the phenomenon of a waterspout would, of course, be seen and naturally avoided. At night, however, such would not necessarily be the case and there would be little warning of its existence in the aircraft's flight path. The spout would probably be too small to give a radar echo and thus give warning of its existence as in the case of a cumulonimbus cloud. Some danger might also arise through the shock of impact at a high speed with a mass of solid water although this would not be likely to occur unless the aircraft was flying very low. Although the waterspout column itself is composed of water droplets formed by condensation from dynamical reduction of pressure, evidence indicates that the more severe storm spouts carry considerable quantities of sea water up to a fair height. In the case of the famous Cottage City spout of 1896 the spray cascade itself rose to a height of 400 ft.

As to the forecasting of conditions suitable for the formation of waterspouts, in the light of present knowledge on the subject, a quotation from Willis Hurd of the U.S. Weather Bureau, who has done considerable work on these phenomena, is apt:—

" It has been shown that waterspouts spring into their brief existence under all manners and combinations of weather circumstances over warm water and

cold water, though most frequently over warm. They are found to occur in weather settled and unsettled; in cyclones and in anticyclones; in calms, light winds, and gales; under all sky conditions from cloudless to overcast; in warm weather and in cold; at all seasons of the year. They are found to rotate in either sense, regardless of their low-pressure centers; to set their courses directly or at angles with or against the prevailing surface winds; to drop from the clouds and rise from the water; to exhibit moderate to terrific forces; to acquire many varieties of shapes and appearances from the ordinary to the grotesque, and to vary in size from small excrescences in the cloud, or mere whirls or protuberances on the water, to cloud-and-sea-spanning creations of monstrous diameter or length."

A. H. GORDON

Periodicities by least squares from sets of six observations daily

When we have a set of observational means u at each of a number of different times of day, there is something intriguing in the attempt to look for diurnal and semi-diurnal periods by threading them on to a curve of the type $u = a_0 + a_1 \sin(t + A_1) + a_2 \sin(2t + A_2)$. This can be done conveniently by the method of least squares, but the method has one serious drawback—it insists on giving a result.

It would be so much more obliging of it if it only gave results when there is a basis of physical reality behind them.

The fact that we get real values of a_1 a_2 A_1 A_2 in the equation above from six values of u (u_1, u_2, . . .) does not justify us in saying that there are periodic causes at work. It only justifies us in saying that if there are periodic causes at work, these are the most likely values for the connected constants. The answer to the " if " may be " yes " or " no ".

In a paper like Dr. Jameson's* the answer is unhesitatingly " yes ", as 864 cases are examined, there is close agreement throughout between observed and computed values, and a high degree of consistency in the values of a_0, a_1, a_2, A_1 and A_2. All this could not occur fortuitously.

However, other cases arise where the evidence is not so convincing, so that it is worth while to call attention to the simple criterion by which, with very little work, we can know how close the least-square sine curve will approach to the observational points from which it is built—which means, roughly, that before starting to build it, we can have a good idea whether it is worth while to do so.

If we deal with six observational means, at four-hourly intervals, per day (u_0, u_1, . . . u_5) it will be found that the sine curve by least squares goes equally near to each of them, alternately above and below.

If $u_0 = z_0 + a_0 + a_1 \sin(t + A_1) + a_2 \sin(2t + A_2)$ it will be found that $6z_0 = u_0 - u_1 + u_2 - u_3 + u_4 - u_5$. Clearly $z_0 = z_2 = z_4$ and these are numerically equal to z_1, z_3 and z_5 but with reversed sign.

No such simple short cut appears to exist if there are 8 or 12 observations, but fortunately, for quite non-mathematical reasons, British ships work in four-hour watches.

*JAMESON, H.; Summary of investigations on the diurnal variation of barometer pressure in tropical seas. *Quart. J. R. met. Soc., London*, **67**, 1941, p. 157.

If r is the range between the greatest and least of the six quantities, $u_0, u_1, \ldots u_5$, it is better to use z/r rather than z, since z/r is numerical and independent of the dimensions of u and z.

Clearly, small values of z/r suggest real periodicities, but do not prove their existence. On occasion a value of $z = 0$ can occur quite fortuitously.

Theoretical considerations indicate that with perfectly random values of $u_0, u_1, \ldots u_5$ the mean value of z/r from a sufficient number of sets of u may be expected to be 0·133, or, since z occurs as $6z$, it may be put more conveniently as $6z/r = 0{\cdot}8$.

I have not burdened this letter with the algebra of the above, but should be happy to discuss it with anyone who might be interested.

If n sets, each of six observations are available, it is easy to find $6z/r$ for each set and hence its average for the whole group.

Unless this mean value is less than 0·8 there seems little point in attempting further analysis by diurnal and semi-diurnal periods. As a small or even zero value of z may occur by chance, the practical question is: how great must n be to provide a reasonable basis? and for any particular value of n, by how much must the mean of $6z/r$ be below 0·8 to justify the use of the sine curve?

There is no absolute rule, but a rough guide has been provided by taking 120 sets of random u's. (Actually each u was the sum of 6 digits taken from the last column of various mathematical tables.) For each set $6z/r$ was obtained, and their mean values taken in successive groups of 2, 3, 4, 5, 6, 8, 10, etc. The mean value of $6z/r$ for the whole 120 groups was 0·797 or almost exactly the theoretical value. In two cases $z = 0$.

For each group of n sets, $120/n$ values of $6z/r$ were thus obtained and plotted; thus the least value of $6z/r$ corresponding to any particular value of n could be read off at once. Admittedly a second experiment with other random data would not give identical figures, but the general smoothness of the graph, including the way in which the 25 percentiles fit in with the factor $1/\sqrt{(n-1)}$, suggests that the 120 sets used were adequate to give a reasonable working basis.

These suggest that for over 15 groups a value of $6z/r$ of less than 0·7 is most unlikely to occur without a real systematic cause that justifies the use of the sine curve. For $n = 10$ the same is true if $6z/r$ is not greater than 0·5, while between 0·7 and 0·5 there appears to be at least a 3 to 1 chance that it is true.

With less than 8 groups it would probably not be wise to make deductions, though in the experiment in question the lowest value of $6z/r$ when $n = 6$ was 0·45.

A further point is the interpretation of values of $6z/r$ considerably above 0·8. Presumably they suggest a systematic cause at work, but one that can be expressed more descriptively by other means than the sine curves in question. A consistent increase at a particular watch only, the other five values of u being identical, would be a case in point, and would give $6z/r = 1{\cdot}0$.

A. J. BAMFORD

19, *Little Paddocks, Ferring, Sussex, July* 4, 1948

Unusual condensation trails

I was interested in the letter from Mr. Dight in your May issue giving an account of other cases of condensation trails formed by the propellors. The point I wished to emphasise, however, in my report of the events of November 29, 1947,* was not the formation of trails by the propellors, which has occurred on other flights from this station, but the formation of ice on the wings where the condensation trails streamed back over them and nowhere else on the aircraft.

I believe that is the first observation of ice accretion formed from a condensation trail. It supports the recently introduced practice of calculating relative humidity and humidity-mixing ratio with respect to a water surface at all temperatures.

E. R. RIPLEY

West Malling, August 5, 1948

NOTES AND NEWS

Very heavy rainfall in Tanganyika

Very heavy rain occurred at Christmas time at Kisawasawa in Tanganyika, over 18 in. falling in two days, causing a landslide and killing several people. Fr. Kosmas at the Kisawasawa Mission (7°51′S. 36°56′E. 900 ft.) reports :—

" The rain began on the 24th at 6.30 p.m. and with the exception of about an hour at midnight continued till 9 a.m. on the 25th. During Christmas Day the sun was shining. But in the evening at 6.30 the rain began again and it was very heavy rain right through the night till 7.30 a.m. of the 26th. Just about after midnight (or at 1 a.m. of 26th) the landslide had happened.

" This heavy rainfall was only local, in length not more than two miles beginning about at the Chonde river on the Kilosa side and passing one mile beyond the Kisawasawa river towards Kiberege."

Although the extremely heavy rainfall was only local, instability conditions were more widespread as shown by the following rainfall reports:—

	Position	Height	Rainfall 24th–25th	Rainfall 25th–26th
		ft.	in.	in.
Kisawasawa Mission	7°51′S. 36°56′E.	900	6·67	11·98
Ruaha Mission	— —	—	3·70	5·00
Ifakara Mission	8°09′S. 36°39′E.	900	2·01	4·22
Tunungao Mission	7°03′S. 37°58′E.	570	0·23	3·94
Kidodi Mission	7°35′S. 37°02′E.	1,100	0·21	1·98
Matombo Mission	7°05′S. 37°46′E.	1,270	1·11	1·20
Ilula Mission	7°40′S. 36°00′E.	4,500	0	1·58

Mr. Grinsted, acting Director, East African Meteorological Service, comments that there was an active convergence zone over the area and that 18 in. of rain in two days is a great deal even for Tanganyika.

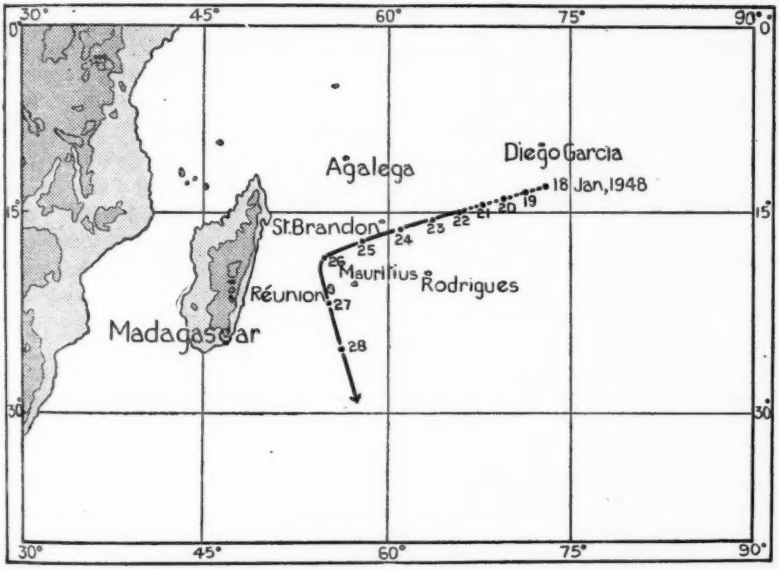
Met. Mag., London, **77**, 1948, p. 17.

Tropical cyclone, south-west Indian Ocean, January 1948

A severe cyclone caused serious damage in the St. Brandon group of islands, (dependency of Mauritius) and at Réunion between January 24 and 27, 1948.

The following statement is a summary of a report on the storm for which we are indebted to Mr. E. C. Davy, Acting Director of the Mauritius Observatory.

First indications of the instability associated with the formation of the storm were a fall of pressure by 1 mb. and unsettled weather at Diego Garcia (see Fig. 1) on the 18th. No centre was located until the 23rd when observations of slowly falling pressure and wind veering from SE. to SW. at St. Brandon and on a ship 50 miles to the east, suggested the existence of a depression centred about 15°S.64°E. During the 24th wind blew at gale to hurricane force at St. Brandon while changing direction from SW. to NW. The reading of a mercury barometer fell to 959 mb. at 1200 G.M.T. and the wind was estimated at the same time to be 125 m.p.h. Part of the eye of the storm was experienced at Long Island, 22 miles south-east of the meteorological station at St. Brandon. At Avocaire, only 13 miles south-east of the meteorological station, the lowest pressure (read on an aneroid) was 940 mb. at about 1200 G.M.T. There was no decrease of wind at the time of this reading. Two islands in the St. Brandon group were washed away and six lives were lost.



On the morning of the 26th the centre was situated at $18\frac{3}{4}$°S.$54\frac{3}{4}$°E. and the recurve towards south and south-east started. The cyclone then moved south-south-east almost over Réunion. Pressure at Réunion fell to 960 mb. and the wind there blowing at hurricane force, changed direction from E. to NE. as the centre passed by. It is known that there was considerable loss of life and material damage at Réunion but full information was not available to Mr. Davy when writing his report.

The cyclone passed Mauritius at a distance of 100 miles. The highest gust recorded there was one of 57 m.p.h.

Mr. Davy considers the cyclone as one of the most intense known in the south Indian Ocean. There is good reason to believe the central pressure was below 940 mb. which compares with readings in the central calm of earlier cyclones of 953 mb. at Mauritius in January 1945 and 947 mb. in 1892.

Tornado, Co. Kildare, Eire

Newspaper cuttings (*Irish Independent* and *Leinster Leader*) have been received from the Director of the Meteorological Service of Eire and from Mr. Walsh, Principal of the Irish Nautical College, Dublin, describing events at Palmerstown House, Kill, Co. Kildare, at 2.30 p.m. on May 31, 1948.

Palmerstown House is a horse-training establishment. A whirlwind is stated to have struck it " with a shrill whistling sound followed by the noise of falling trees ". Previously there had not been much wind and only light rainfall. The roof of a long line of horse boxes was torn away, heavy supports smashed, and concrete blocks ripped from the walls. Joists from the stables were found half a mile away. In the grounds full-size beech trees were torn up by the roots. One beech tree was snapped off at ground level and carried 30 yd. The trail of damage was about 800 yd. long. One tree had its branches slashed downwards while others nearby were undamaged.

Fresh polar air covered Ireland on May 31 and cumulonimbus cloud and squally showers were general. A shallow depression moved north-east from central Ireland to north-west England during the day. No definite front could be traced as crossing Kildare at the time of the phenomenon.

The events seem to have been due to a small tornado. Tornadoes in the British Isles have generally been associated with a sharp cold front but the occurrence of one would not have been impossible in the general weather conditions of May 31.

The report is of interest as a search through the literature revealed no previous record of a tornado in Ireland.

REVIEWS

Mikroklimatikus mérések dohányban és napraforgóban (Microclimatological observations on tobacco and sunflower), by D. Berényi. Bulletin of the Meteorological Institute of the University of Debrecen, No. 8. 8vo, 9½ in. × 6¾ in. pp. 59. Debrecen, 1948.

This bulletin contains two papers, the first of which gives the results of experiments on the microclimate of tobacco with different plant-spacing and also on the microclimate of two varieties of tobacco. In these experiments air temperatures in the crops were measured with standard station thermometers at heights of 5, 100, 150 cm., and the soil temperature at a depth of 5 cm. A hair hygrometer and a Piché evaporimeter were used to give measurements of humidity and evaporation at 5 and 150 cm. Temperatures were also measured at 5 and 150 cm. in an open situation outside the crops. Observations were made every hour from 0800 to 2000.

The plant-spacings compared were 70 × 50 cm. and 60 × 40 cm. and a comparison of the mean hourly temperatures over 7 days leads to no unex-

pected results. At 5 cm. the mean daily temperature in the open is 0·2°C. higher than in the widely spaced crop and 0·9°C. higher than in the closely spaced. The greatest difference is at 1400 when the mean temperature in the open is 1·0°C. higher than in the 70 × 50 cm. crop and 2·1°C. higher than in the 60 × 40 cm. At 150 cm. the differences are much smaller. Spacing affects the soil temperature at 5 cm. which is 0·5°C. higher under the wider than under the closer spacing; in the middle of the day the mean differences reach 1°C.

Evaporation and saturation deficits over the whole day are greater in the wider spacing both at 5 cm. and 150 cm. but differences in relative humidity are only slight. The vapour pressure at 5 cm. is greater in the widely spaced crop, but at 150 cm. it is greater in the closer spacing. Although these results may be true for the day as a whole, it is sometimes difficult to reconcile the mean hourly values given by the author in various tables.

The second experiment was arranged to find the difference between the microclimates of Debreceni and Szabolcsi varieties of tobacco with both of them planted at intervals of 60 × 40 cm. Air temperatures, soil temperatures and evaporation are higher in the Debreceni crop and the author therefore concludes that the Szabolcsi variety is more suitable in dry regions.

The second paper gives the results of measurements in sunflower (spacing 70 × 60 cm.) and in Debreceni tobacco. The height of the sunflower, 2·5–3 m., prevents the air near the soil from warming up until late in the forenoon and it is cooler at 5 cm. than at 300 cm. until about 0900, and also after about 1700.

Some comparison is given between various heights in sunflower, tobacco and in the open field, but differences in the heights make it difficult to draw any conclusions from the results. There may well be good reasons for taking observations at 300, 150 and 20 cm. in the sunflower and at 150, 100 and 5 cm. in tobacco and in the open, but unfortunately they are not mentioned in the English summary. It is therefore difficult to accept with confidence the conclusion: "Tobacco has a more extreme microclimate than sunflower, and this is characterised by a quick cooling down and a stronger warming up."

The English summaries must be used with some care and the statements should always be checked against the tables and diagrams. No doubt some of the difficulties are purely linguistic, but others appear to be due to inadequate statistical analysis of results. Two examples of this are given below:—

(i) On p. 28 § 9(*c*) it is stated that the increase of evaporation at 5 cm. is 19 per cent. greater in the closely spaced tobacco than in the widely spaced (relative to the air temperature at 150 cm. in the open). This statement is based on the regression equations given on p. 20, viz.:—

$$\text{Evaporation (wide spacing)} = 0{\cdot}023\,T - 0{\cdot}25$$
$$\text{Evaporation (close spacing)} = 0{\cdot}0273\,T - 0{\cdot}41$$

where T is the temperature in the open. These regression lines are shown in Fig. 29, but as the standard errors of the regression coefficients are not given, it is impossible to judge whether the lines are significantly different.

(ii) On p. 53 § 1, it is stated that wind has a significant role in the development of the vertical temperature gradients, though cloudiness has obviously

more influence. However, the correlation coefficient between the mean lapse in the sunflower crop and the mean wind force is only about 0·30, which would be expected about 3 times out of 10 by chance, even if there were no correlation between the observations. The correlation coefficient between the temperature lapse and cloudiness is about 0·58, which would not be expected as frequently as once in 20 times by chance and can therefore be taken as significant.

There is, however, no doubt of the value of the experiments which have been carried out by Professor Berényi, experiments which must be repeated in other crops and with carefully planned replication. It will then be possible to assess within definable limits the effect of different crops and cultural practices on the microclimate of any locality.

W. H. HOGG

A contribution to the study of storm surges on the Dutch coast, by W. F. Schalkwijk. *Meded. Verh. Ned. met. Inst., De Bilt*, Serie B, **1**, Nr. 7. 4to. 12½ in. × 9 in. pp. iv + 111. Rijksuitgeverij/'s-Gravenhage, 1947. Price 10 *florins*.

The term " storm surge " is used to denote changes of sea level associated with meteorological factors. The observed tide at a place may differ from the astronomical or predicted tide, the difference depending upon the meteorological elements wind and atmospheric pressure. When this difference is additive and occurs at or near the time of high tide coastal defences may be threatened. The economic importance of a " Warning service for storm surges " in a country like Holland is at once apparent.

Interest in the subject in this country was given an impetus by the disastrous floods in the Thames during the night of January 6–7, 1928, reports being made by Doodson and Dines*. Later work has been done by Doodson, Proudman and Corkan.

The present contribution starts with a useful historical survey of considerable interest to the meteorologist and requiring no specialised knowledge. The theory of the wind effect is then developed from the fundamental equations, assuming a stationary homogeneous wind field, and applied to the cases of an enclosed sea and a bay, the latter representing the idealised form of the North Sea, regarded as closed at its southern end; the modifying effect of the English Channel is shown to be small. Investigations are later made on the effect of a non-homogeneous wind field and a non-stationary state.

The application of these results to selected storm surges is then considered in detail, values of wind over the North Sea being deduced from synoptic charts. The agreement found between the theoretical and empirical results is as high as could be expected bearing in mind the various approximations used. The author gives plausible reasons for the discrepancies and for the differences between the present and previous investigations.

Most forecasting rules used in the past have been statistical in character. The aim of this work is the derivation of a general method of predicting the development of individual storm surges from the expected development of the barometric field. This change in outlook is of great importance.

T. H. KIRK

*DOODSON, A. T.; Report on the Thames floods, and DINES, J. S.; Meteorological conditions associated with high tides in the Thames. *Geophys. Mem., London*, **5**, No. 47, 1929.

Catalogue No. 684. *Meteorological and Scientific Instruments.* C. F. Casella & Co., Regent House, Fitzroy Square, W.1.

Messrs. Casella's new catalogue is issued with price list No. 699, dated June 1948. To their extensive range of meteorological instruments Messrs. Casella have now added the Gold visibility meter and the Duvdevani dew gauge. Besides details of the instruments the catalogue contains much sound advice on their exposure and reading.

NEWS IN BRIEF

The L.G. Groves Memorial Prize for Meteorology has been awarded this year to Dr. Ronald Frith, Principal Scientific Officer in the Meteorological Office, for his valuable services rendered as senior Meteorological Officer of the Meteorological Research Flight.

Mr. J. K. Bannon was announced as *proxime accessit.*

The L.G. Groves Memorial award for Meteorological Air Observers has been won this year by Flight Sergeant P. G. White, R.A.F.V.R. Meteorological Observer, for meritorious work and devotion to duty.

The presentation ceremony took place in the Air Member for Personnel's room on October 19, 1948. The presentations were made personally by Major Groves who was accompanied by Mrs. Groves.

We have received a letter from the Occupational Therapist at Napsbury Hospital, near St. Albans, saying that she would like to run a simple form of meteorological station for the patients. The main point in this connexion is that they should feel that the work is of some use outside the hospital. The major difficulty is the price of instruments. If any readers have a standard 5-in. rain-gauge or thermometers, with N.P.L. certificates, which they no longer require and would be willing to present them to the hospital will they please communicate with:—

Miss Mary K. Goodman, Occupational Therapist,
28 Sandringham Road, Bromley, Kent.

WEATHER OF SEPTEMBER 1948

Many depressions moved north-eastwards between Scotland and Iceland and three eastwards across the British Isles, crossing northern England on the 3rd and 15th and southern England on the 12th. After the 15th anticyclones were centred over or near to England, mostly over the Channel or its western approaches, but over central Europe from the 23rd to the 28th.

Mean pressure for the month was below 1005 mb. from southward of Iceland to northern Norway, and 1020 mb., or slightly over, in northern France and south-westwards beyond the Azores. It was more than 5 mb. below normal between north-east Scotland and northern Scandinavia but generally within about 2 mb. of normal in an area extending from the eastern parts of the U.S.A. to Russia and the Mediterranean.

In the British Isles unsettled weather prevailed generally for the first half of the month. Subsequently anticyclonic conditions were established over southern England and continued until the end of the month, apart from a break on the 27th–28th. Unsettled conditions persisted, however, in the west and

north. It is interesting to note that whereas the number of days without measurable rain at Stornoway in the northern Hebrides was only one, at some stations in south-east England the number was 22.

During the opening days an Atlantic depression moved east across northern England to the North Sea and filled. Heavy rain occurred in western districts on the 1st and more generally on the 2nd, with the local thunderstorms in the west. Showers and scattered thunderstorms occurred on the 3rd and 4th. On the 7th and 8th an anticyclone over the Bay of Biscay moved north-east, while a depression westward of Scotland moved rather quickly north-east to the north of Norway. Strong winds occurred in the west and north, reaching gale force locally and rain fell at times, particularly in the west on the 7th and in the neighbourhood of a slow-moving front stretching from north-east England to south Wales on the 8th. Temperature rose and touched 79°F. in parts of London on the 9th. In the following days a new depression on the Atlantic moved north-north-east, while associated troughs crossed the British Isles giving further rain. On the 12th a small depression moving across southern England was associated with considerable rain there, while on the 14th and 15th another small disturbance moved rapidly east-north-east from mid Atlantic across southern Scotland to the North Sea, giving rain, heavy in places, in the northern half of the country. Gales were recorded locally on the 12th, 13th and 15th. Subsequently an anticyclone became established off our south-west coasts and dominated conditions over England until the 19th, when a cold front moved south over the country giving some slight rain in the west and north. Thereafter another anticyclone situated south-east of Greenland, moving rather quickly south-east, reinforced the one off our south-west coasts, and cool weather prevailed, with scattered rain, chiefly in the west and north. Slight screen frost occurred locally on the 21st and 22nd and in Scotland also on the 23rd, with ground frost in many places. By the 24th the highest pressure was situated over central Europe and a wedge extended west over southern England. Meanwhile the north-east Atlantic was covered by a complex area of low pressure and the air supply over the British Isles was drawn from the south; temperature rose appreciably and approached 80°F. in parts of London on the 26th. From the 26th to 28th vigorous depressions moved north-east along our north-west seaboard; gales occurred in the north-west and north and considerable rain fell in Scotland, north Ireland and northern England on the 26th. Some slight rain fell also in southern England on the 27th and 28th. Apart from slight showers in the north-west and north fair weather prevailed during the closing days but a trough of low pressure moving north-east over north-west Scotland brought further rain in the north-west late on the 30th.

The general character of the weather is shown by the following table:—

	Air Temperature			Rainfall		Sunshine	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days' difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales	79	27	+0·9	113	0	87	33
Scotland	72	21	+0·7	156	+5	93	29
Northern Ireland..	70	33	+1·2	146	+5	80	25

RAINFALL OF SEPTEMBER 1948

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ..	1·34	74	*Glam.*	Cardiff, Penylan ..	4·18	137
Kent	Folkestone, Cherry Gdns.	2·55	108	*Pemb.*	St. Ann's Head ..	3·12	109
,,	Edenbridge, Falconhurst	2·08	92	*Card.*	Aberystwyth	3·65	128
Sussex	Compton, Compton Ho.	3·76	135	*Radnor*	Bir. W. W., Tyrmynydd	5·30	137
,,	Worthing, Beach Ho.Pk.	1·63	76	*Mont.*	Lake Vyrnwy	4·95	131
Hants	Ventnor, Roy. Nat. Hos.	1·54	62	*Mer.*	Blaenau Festiniog ..	16·34	207
,,	Bournemouth	2·50	107	*Carn.*	Llandudno	2·01	94
,,	Sherborne St. John ..	2·20	107	*Angl.*	Llanerchymedd ..	3·76	128
Herts.	Royston, Therfield Rec.	1·88	100	*I. Man.*	Douglas, Boro' Cem. ..	5·40	165
Bucks.	Slough, Upton	1·73	98	*Wigtown*	Port William, Monreith	4·72	162
Oxford	Oxford, Radcliffe ..	2·48	145	*Dumf.*	Dumfries, Crichton R.I.	4·93	182
N'hant.	Wellingboro', Swanspool	2·18	121	,,	Eskdalemuir Obsy. ..	6·97	186
Essex	Shoeburyness	·98	59	*Roxb.*	Kelso, Floors	2·42	127
Suffolk	Campsea Ashe, High Ho.	1·79	94	*Peebles*	Stobo Castle	3·60	143
,,	Lowestoft Sec. School ..	·90	46	*Berwick*	Marchmont House ..	2·41	100
,,	Bury St. Ed., Westley H.	1·47	74	*E. Loth.*	North Berwick Res. ..	2·58	123
Norfolk	Sandringham Ho. Gdns.	2·31	112	*Midl'n.*	Edinburgh, Blackf'd. H.	2·58	126
Wilts.	Bishops Cannings ..	2·32	106	*Lanark*	Hamilton W. W., T'nhill	5·87	219
Dorset	Creech Grange.. ..	3·18	116	*Ayr*	Colmonell, Knockdolian	4·69	135
,,	Beaminster, East St. ..	3·19	125	,,	Glen Afton, Ayr San ..	5·96	153
Devon	Teignmouth, Den Gdns.	1·22	62	*Bute*	Rothesay, Ardencraig	3·39	207
,,	Cullompton	1·58	70	*Argyll*	L. Sunart, Glenborrodale	10·26	164
,,	Barnstaple, N. Dev. Ath.	2·21	82	,,	Poltalloch	8·96	196
,,	Okehampton, Uplands	2·44	75	,,	Inverary Castle.. ..	13·86	216
Cornwall	Bude School House ..	1·80	73	,,	Islay, Eallabus ..	7·20	172
,,	Penzance, Morrab Gdns.	1·86	63	,,	Tiree	6·65	179
,,	St. Austell, Trevarna ..	2·45	77	*Kinross*	Loch Leven Sluice ..	4·11	160
,,	Scilly, Tresco Abbey ..	·90	35	*Fife*	Leuchars Airfield ..	2·67	138
Glos.	Cirencester	2·54	115	*Perth*	Loch Dhu	11·42	199
Salop.	Church Stretton ..	2·58	122	,,	Crieff, Strathearn Hyd.	..	..
,,	Cheswardine Hall ..	3·24	159	,,	Pitlochry, Fincastle ..	3·56	142
Staffs.	Leek, Wall Grange P.S.	2·02	81	*Angus*	Montrose, Sunnyside ..	1·93	97
Worcs.	Malvern, Free Library	2·75	143	*Aberd.*	Balmoral Castle Gdns...	1·80	75
Warwick	Birmingham, Edgbaston	2·81	157	,,	Dyce, Craibstone ..	1·81	75
Leics.	Thornton Reservoir ..	2·61	144	,,	Fyvie Castle	1·96	75
Lincs.	Boston, Skirbeck ..	2·31	131	*Moray*	Gordon Castle	2·57	103
,,	Skegness, Marine Gdns.	2·68	148	*Nairn*	Nairn, Achareidh ..	2·40	114
Notts.	Mansfield, Carr Bank ..	2·25	122	*Inv's*	Loch Ness, Foyers ..	4·42	150
Ches.	Bidston Observatory ..	1·62	67	,,	Glenquoich	15·65	181
Lancs.	Manchester, Whit. Park	2·10	88	,,	Fort William, Teviot ..	13·78	216
,,	Stonyhurst College ..	4·06	106	,,	Skye, Duntuilm ..	8·74	190
,,	Blackpool	4·60	161	*R. & C.*	Ullapool	4·62	127
Yorks.	Wakefield, Clarence Pk.	1·14	71	,,	Applecross Gardens ..	8·96	179
,,	Hull, Pearson Park ..	1·35	78	,,	Achnashellach	11·93	173
,,	Felixkirk, Mt. St. John	1·82	100	,,	Stornoway Airfield ..	7·18	191
,,	York Museum	1·20	74	*Suth.*	Lairg	3·61	128
,,	Scarborough	1·54	86	,,	Loch More, Achfary ..	11·73	204
,,	Middlesbrough.. ..	1·17	71	*Caith.*	Wick Airfield	3·10	124
,,	Baldersdale, Hury Res.	3·87	155	*Shet.*	Lerwick Observatory ..	5·64	187
Nor'd.	Newcastle, Leazes Pk. ..	3·66	185	*Ferm.*	Crom Castle	3·77	135
,,	Bellingham, High Green	3·97	165	*Armagh*	Armagh Observatory ..	2·64	107
,,	Lilburn Tower Gdns. ..	1·98	84	*Down*	Seaforde	3·16	115
Cumb.	Geltsdale	5·08	181	*Antrim*	Aldergrove Airfield ..	4·30	173
,,	Keswick, High Hill ..	6·07	165	,,	Ballymena, Harryville..	4·51	145
,,	Ravenglass, The Grove	5·70	169	*Lon.*	Garvagh, Moneydig ..	4·49	151
Mon.	Abergavenny Larchfield	2·81	120	,,	Londonderry, Creggan	6·16	187
Glam.	Ystalyfera, Wern House	8·76	200	*Tyrone*	Omagh, Edenfel ..	4·78	157

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, MAY 1948

Stations	Pressure		Temperatures							Relative humidity	Mean cloud amount	Precipitation			Bright Sunshine	
			Absolute		Mean values											
	Mean of day M.S.L.	Diff. from normal	Max.	Min.	Max.	Min.	½ Max. + ½ Min.	Diff. from normal	Wet bulb			Total	Diff. from normal	Days	Daily mean	Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	tenths	in.	in.		hr.	%
London, Kew Observatory	1015·5	−0·1	77	34	63·5	45·7	54·6	−0·1	49·9	70	5·5	2·22	+0·50	9	7·5	48
Gibraltar	1014·9	−1·2	81	51	72·1	59·0	65·5	0·0	60·4	76	5·3	2·87	—	10	8·6	61
Malta	1013·7	−0·8	81	54	74·8	60·9	67·9	+2·0	64·2	68	3·7	0·08	—	2	9·8	70
St. Helena	1016·6	−0·3	70	56	68·3	58·5	63·4	+0·8	59·0	93	8·5	2·08	−0·46	13	—	—
Freetown, Sierra Leone	1011·8	+2·2	89	69	85·0	75·0	80·0	−0·5	76·1	82	6·6	7·70	−3·77	15	5·8	46
Lagos, Nigeria ..	1011·5	+0·9	92	69	88·1	72·4	80·3	−1·5	77·7	85	8·6	8·98	—	15	4·4	35
Kaduna, Nigeria ..	1009·3	—	94	64	87·8	69·9	78·9	−1·0	73·1	76	8·3	4·89	−0·88	11	7·1	56
Chileka, Nyasaland ..	1019·1	+0·1	85	53	78·5	59·5	69·0	+1·0	63·4	69	3·8	0·06	−0·24	3	7·7	67
Lusaka, Rhodesia ..	1016·4	+0·4	84	50	78·5	55·2	66·9	+1·8	59·8	65	3·1	0·19	+0·14	2	9·8	86
Salisbury, Rhodesia ..	1019·0	+0·3	81	43	75·8	49·6	61·7	+0·6	56·3	68	1·9	0·67	+0·29	2	9·1	81
Cape Town ..	1017·3	−0·8	81	44	69·0	53·6	61·3	+2·4	53·4	78	7·0	4·00	+0·25	16	—	—
Germiston, South Africa	1032·5	—	71	37	66·9	45·3	56·1	—	47·1	72	2·7	0·58	—	3	9·3	86
Mauritius																
Calcutta, Alipore Obsy.	1001·6	−2·0	98	71	93·4	79·0	86·2	+0·1	80·8	80	6·8	3·78	−1·78	12	8·1	61
Bombay	1006·5	−0·9	94	79	92·5	81·7	87·1	+1·3	78·0	71	4·4	0·00	−0·55	0	9·8	75
Madras	1004·0	−1·4	110	77	102·0	83·7	92·9	+3·1	78·3	62	5·2	0·32	−1·52	2	9·5	75
Colombo, Ceylon ..	1008·9	+0·5	89	73	87·4	78·3	82·9	+0·1	78·1	87	7·5	6·60	−4·34	25	6·3	51
Singapore	1008·7	0·0	95	73	89·5	75·9	82·7	+0·7	77·1	83	6·6	9·75	+3·11	18	—	—
Hong ong	1010·1	+1·0	92	69	83·8	74·9	79·3	+1·9	76·0	88	—	9·14	−2·93	26	4·9	37
Sydney, N.S.W. ..	1016·1	−2·3	78	44	67·5	51·1	59·3	+0·5	51·4	67	3·6	5·31	+0·13	6	7·3	70
Melbourne	1016·5	−2·7	75	41	59·5	47·0	53·3	−0·8	49·7	81	6·8	1·83	−0·33	18	2·8	28
Adelaide	1021·1	+0·9	81	42	63·3	50·7	57·0	−1·0	51·8	73	6·9	3·11	+0·39	17	4·0	39
Perth, W. Australia ..	1022·1	+3·7	83	47	72·6	51·4	62·0	+1·3	56·0	61	3·0	1·04	−3·93	9	6·7	64
Coolgardie	1023·8	+4·7	82	37	69·9	45·7	57·8	+0·1	50·1	61	2·3	0·01	−1·32	1	—	—
Brisbane	1017·2	−1·4	83	43	73·5	53·7	63·6	−1·0	55·9	59	2·7	4·90	+2·09	6	8·4	78
Hobart, Tasmania ..	1009·3	−6·0	65	38	55·3	43·2	49·3	−1·2	44·7	73	7·5	2·46	+0·56	18	3·4	35
Wellington, N.Z. ..	1009·1	−6·5	63	40	56·8	47·4	52·1	+0·7	49·9	82	7·5	7·92	+3·24	21	3·6	36
Suva, Fiji	1012·1	−0·6	87	64	81·4	71·5	76·5	0·0	73·2	84	7·1	7·93	−2·14	20	5·4	48
Apia, Samoa	1010·5	−0·2	90	72	86·3	74·8	80·5	+0·8	77·8	82	7·8	10·63	+4·10	29	5·9	51
Kingston, Jamaica ..	1012·5	−0·6	91	70	88·8	74·4	81·6	+1·9	75·9	76	5·0	9·21	+4·82	7	7·8	60
Grenada, W. Indies ..	—	—	88	73	86·4	76·6	81·5	+1·8	77·9	81	8·3	2·60	−1·59	16	—	—
Toronto	1013·6	−1·3	75	35	61·4	45·2	53·3	−0·5	45·2	68	6·6	2·64	−0·15	12	6·9	47
Winnipeg	1016·0	+2·2	95	24	67·2	40·7	53·9	+1·9	41·0	72	3·9	1·70	−0·30	4	7·3	47
St. John, N.B. ..	1014·2	+0·3	68	32	54·8	40·4	47·6	−0·1	44·2	85	8·3	5·09	+1·38	21	4·5	30
Victoria, B.C. ..	1014·8	−1·9	76	33	59·9	45·3	52·6	−0·4	46·0	92	7·6	4·02	+2·89	16	7·3	48